Sustainable Freight: Impacts of the London Congestion Charge and Low Emissions Zone

Andrea Broaddus (corresponding author)
Department of City & Regional Planning
University of California at Berkeley
228 Wurster Hall, #1850
Berkeley, CA 94720-1850
Tel: 510-219-6692
Fax: 510-642-1641
abroaddus@berkeley.edu

Michael Browne
University of Westminster
Faculty of Architecture and the Built Environment
35 Marylebone Rd
London NW1 5LS
Tel: +44 (0)20 7911 5000 ext 65154
Fax: +44 (0)20 7911 5057
m.browne@westminster.ac.uk

Julian Allen
University of Westminster
Faculty of Architecture and the Built Environment
35 Marylebone Rd
London NW1 5LS
+44 (0)20 7911 5000 ext 66627
Fax: +44 (0)20 7911 5057
allenj@westminster.ac.uk

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ABSTRACT

This paper assesses whether two sustainability policies currently in effect in London, a congestion charge zone and a low emission zone, have affected freight operations and reduced vehicle kilometers travelled. It investigates responses by freight operators, including re-timing, re-routing, or reducing the number of trips, or replacing vehicles. Freight traffic trends from 1994 to 2012 were identified using road traffic estimates, cordon counts, and vehicle speed data and supplemented by interviews with freight industry experts and operators. Goods traffic increased throughout London during this timeframe, but declined in Central London. Findings indicate that freight traffic was insensitive to the congestion charge, but may have benefitted from time travel and journey reliability savings resulting from lower volumes of discretionary traffic. Price elasticity of demand was estimated as -04 to -.06 for LGVs, and as perfectly inelastic for MGVs and HGVs in the long run. The congestion charge may have time-shifted some light goods trips, but most freight trips face a variety of constraints on operators' delivery window. However improved operational efficiency through greater vehicle load consolidation may have occurred. The relocation of logistics depots and warehouses from central and Inner London to Outer London also played a role. No evidence was found of re-routing of freight traffic or avoidance traffic around the charged zone. The low emission zone spurred higher levels of operational change than the congestion charge zone, and it was effective at spurring freight vehicle replacement. The paper also discusses freight operators' perceptions of these policies and how they could be improved.

Keywords: congestion charge, low emission zone, sustainable freight, VKT reduction

INTRODUCTION

Sustainable transport policies fall into three main policy mechanisms for reducing emissions: setting vehicle standards requiring low-emission vehicles, creating incentives encouraging conversion to low-emission fuels, and using pricing to reduce vehicle kilometers travelled (VKT).Over the past two decades, London has taken bold steps implementing policies of all three types. This paper considers two policies are currently in effect: a congestion charge zone (pricing), and low emission zone (vehicle standard). Both of these policies were first-of-a-kind in the UK, and among the largest in scope of their kind in the world.

Specific responses from the freight sector have been required, because goods vehicles are major contributors to particulate and smog emissions. Road freight accounts for about 240 million tonnes (28%) of PM10, 5,500 million tonnes (17%) of NO2, and 250 million tonnes (4%) of London's carbon dioxide emissions [1]. Freight is a derived demand that increases with population growth and follows the economic cycle. Thus while London has experienced a long-term decline in private automobile traffic since 1999, goods traffic has continued to increase, aside from a downturn during the recession from 2007 to 2012 (Figure 1).

The low emission zone (LEZ) was targeted at the freight sector to encourage replacement of the most polluting heavy vehicles, and affects all vehicles operating in Greater London equally (an area of 600 square miles). The congestion charge zone (CCZ) affects only vehicles circulating within an area of central London defined by a cordon (an area of 8 square miles) Both policies are enforced using an Automated Number Plate Recognition (ANPR) system. Their boundaries are shown in Figure 2.

This paper investigates the many potential ways that freight operators could have adjusted their operations in response to the CCZ and LEZ. We begin with a discussion of freight demand and how operators are expected to respond to and benefit from pricing measures like the CCZ. Our aim in this paper is not to contrast and compare these policies as competing approaches, but to consider their combined impact on a particular road user group and whether it represents progress toward sustainability goals. The freight industry represents a baseline of vehicle emissions that must be addressed by sustainable transport policies, but it is a somewhat captive user group with many types of constraints and so results may not be as expected. Much of the freight data presented in this paper has not been previously published, but was provided to the researchers by Transport for London (TfL).

FIGURE 1. Annual VKT trend in London, all roads (1993=100). [2]

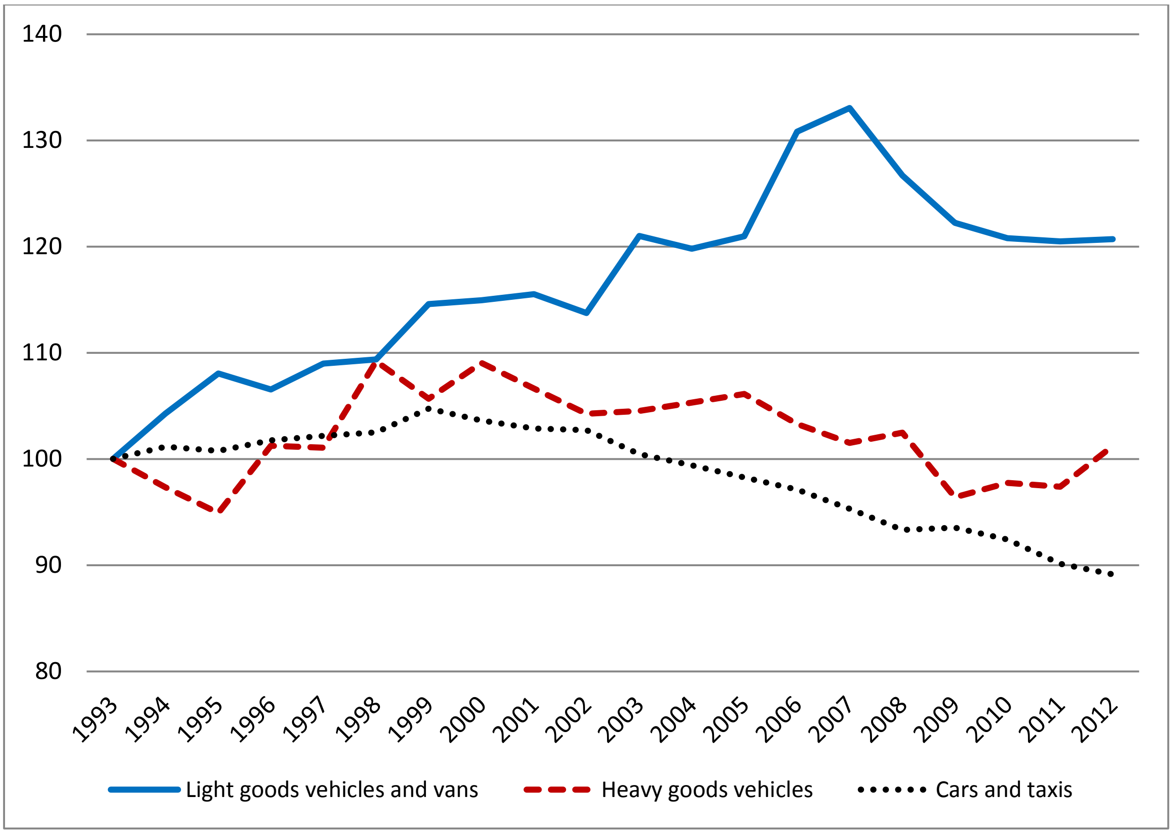
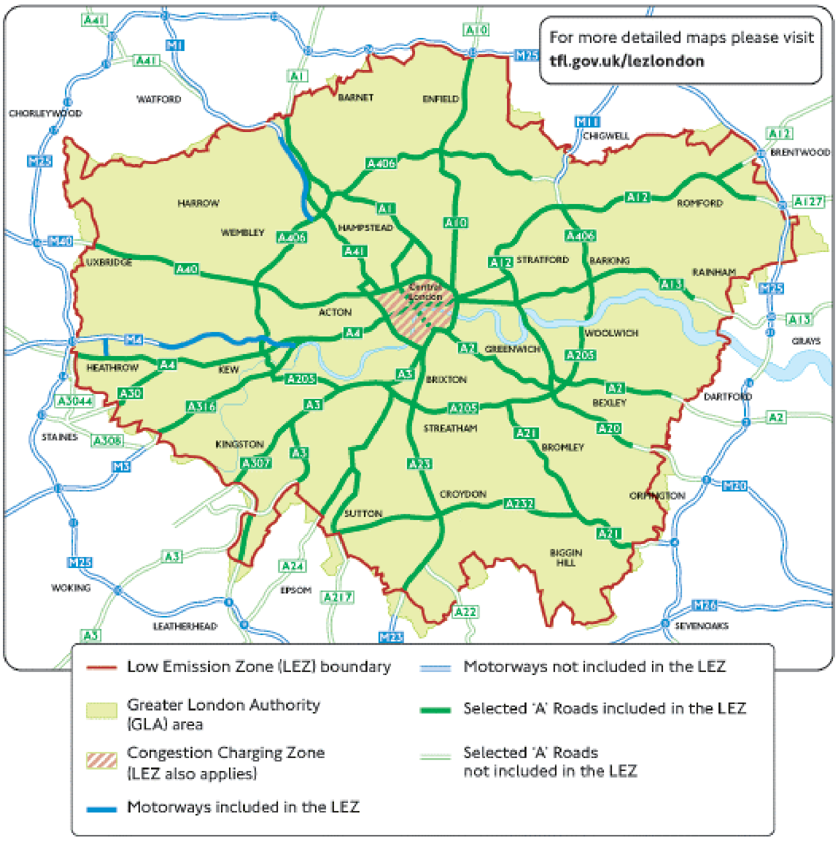


FIGURE 2. Boundaries of the CCZ, LEZ, and traffic count cordons [3]



London

Greater London has approximately 8.4 million residents and 4.3 million jobs. The congestion charge cordon roughly defines London's central business district, containing 1.3 million jobs and only 175,000 residents. [4, 5] It contains most of London's most popular historic, cultural and shopping destinations, which are visited by over 15 million international tourists annually. [6] The charged area contains over half of Greater London's office space (15 million square feet), 15% of retail space (2 million square feet), and 2% of warehouse space (200,000 square feet). [7]

This paper makes reference to Inner, and Outer London, which are defined geographies used in statistical reporting. Inner London consists of the fourteen innermost boroughs, and Outer London as the remaining eighteen boroughs. Inner London has a much higher density (26,000 people per square mile), than Outer London (10,000 people per square mile). Central London may be defined differently depending on the context; it in this paper it refers to the congestion charge zone.

Congestion charge zone

Introduced in February 2003, the CCZ covers London's central business district, an area of eight square miles. All vehicles entering the zone are required to pay a daily fee during business hours (07:00 to 18:00). When it was introduced, the fee was £5, but it is currently £11.50 (about $19.50). There is an exemption for vehicles which emit 75g/km or less of CO_2, the Euro V standard for air quality (the European Union sets vehicle emissions standards for vehicles sold within member states, referred to by the iteration of revision with Roman numerals for goods vehicles). Freight operators with more than six vehicles are eligible for a fleet discount of £1 per vehicle per day. The congestion charge area was expanded in 2008 to include a 'western extension' area, but this was removed in response to residents' complaints in 2011. Transport for London, which operates the scheme, is committed to keeping the CCZ as simple as possible, and so no further expansion or differentiated pricing is under consideration or likely.

Traffic volumes fell by an estimated 20% within the CCZ when it was implemented, and have remained stable over the decade [8]. Vehicle travel speeds increased in the early years, but gradually declined over time due to roadworks and roadspace reallocation, such that average traffic speeds in the zone today are approximately equivalent to what they were ten years ago [8]. A major program of roadworks was undertaken during the first few years of congestion charging. It entailed maintenance and repair of key utilities located beneath London's road network, including gas, electricity, telephones, water supply, and sewage. Roadspace reallocation in the charged zone included the expansion of exclusive bus and cycle lanes as well as pavement widening. For example, dedicated bus lanes in the zone grew from 24.5 miles in 2003 to 26.5 in 2007. [9] Bus and cycle traffic priority measures and junction redesign for safety purposes contributed to reduced traffic speeds. For example, signals were retimed and new crossings installed to prioritize pedestrian safety. These measures contributed to an estimated as a 30% decrease in network capacity in central

London between 1993 and 2009, despite increasing after the initial introduction of the CCZ [8]. Freight curbside delivery zones were protected during these changes.

Low Emission Zone

The LEZ was introduced in February 2008 [10]. It sets minimum emission standards for heavy vehicles operating throughout Greater London (600 square miles), and is in force 24 hours per day, every day of the year. Non-compliant vehicles must pay a fee of £200 per day for vehicles 3.5 tonnes and heavier, and £100 per day for 1.2 tonne vehicles. The LEZ had a phased introduction of increasingly tough emissions standards and inclusion of vehicles. The Phase 1 emissions standard was Euro III for HGVs over 12 tonnes. In July 2008, Phase 2 extended this standard to 3.5 tonne vehicles, buses and coaches. Approximately 90% of the existing goods vehicle fleet was compliant at that point [11]. Older vehicles could be retrofitted with a filter or converted to natural gas, but no government assistance was offered to assist with equipment purchases or truck replacement.

Phase 3 of the LEZ was originally planned for introduction in October 2010, but was deferred until January 2012 by a newly elected Mayor in response to stakeholder concerns about the recession [12]. It extended the Euro III standard for particulate matter to all diesel powered vehicles in London, including LGVs and a range of other commercial, civic and personal vehicles, including: minibuses up to 5 tonnes; ambulances, fire trucks, garbage trucks and motorhomes over 2.5 tonnes; large vans, pick-up trucks and 4x4 utility vehicles over 1.2 tonnes. Vehicles registered as new after January 1 2002 automatically met this standard, as that was the date for manufacturer compliance. Since it was pushed back, the introduction of Phase 3 coincided with the planned date for LEZ Phase 4 requirements, which raised the emissions standard for HGVs over 3.5 tonnes to Euro IV. Vehicles registered as new after October 1 2006 automatically met this standard. LEZ vehicle compliance rates have risen over time, and by March 2014 compliance rates were 99.3% for Phase 3 vehicles and 97.0% per cent for Phase 4 vehicles [13].

METHODOLOGY

Our research questions are as follows. Have the CCZ and LEZ policies spurred changes toward more sustainable freight operations in terms of types of vehicles, routes, number of trips, and ultimately VKT? Have operators been able to realize operating efficiencies, such as time and fuel cost savings, that offset costs of compliance? To investigate these questions, we first developed a set of potential responses by operators. Table 1 summarizes our list of expected responses to the CCZ and LEZ, based upon both explicit policy goals and anticipated changes due to indirect effects.

TABLE 1. Expected responses to the CCZ and LEZ policies

Expected responses	Congestion charge	Low emission zone
Re-time trips	X	
Re-route trips	X	
Reduce number of trips (traffic counts)	X	
Reduce vehicle kilometers travelled (VKT)	X	X
Replace/redeploy most polluting vehicles		X

We then sought evidence of whether these expected responses have indeed transpired. Publicly available data and reports were supplemented by a few personal interviews with freight industry experts and operators. Traffic trends over time were identified using road traffic estimates produced by the Department for Transport and Transport for London.

Traffic flow data are collected continuously on a network of automated counters on motorways and major roads (A roads), supplemented by manual counts (from 7:00 to 19:00) to identify vehicle type. VKT estimates are calculated for each link of the network by multiplying average daily traffic flow by the length of the road link, and then by 365 days per year. In order to compare VKT consistently across the network, trends were calculated and mapped as annual VKT per road kilometer. In these data, a light goods vehicle (LGV) refers to vehicles with a gross weight up to and including 3.5 tonnes, whereas heavy goods vehicle (HGV) refers to vehicles with a gross weight over 3.5 tonnes.

Cordon crossing counts are conducted manually at three concentric cordons in London, a central cordon slightly outside the congestion charge boundary, an inner cordon approximately 10 miles from the center, and a boundary cordon on the administrative edge of London, roughly equivalent to the M25 orbital motorway (these are visible in Figure 2). Historically these counts were not conducted at each cordon every year, but rotated such that counts were taken at each cordon once in three years. Since 2001, central cordon counts have been conducted annually. In order to compare cordon counts with each other, missing years were imputed. In these data, goods vehicles are reported as light, medium, and heavy. Light goods vehicle (LGV) refers to vehicles with 2-axles, 4 wheels with a gross weight up to and including 3.5 tonnes, medium gods vehicle (MGV) refer to vehicles with 2-axles, 6 wheels and a gross weight over 3.5 tonnes, and heavy goods vehicle (HGV) refers to vehicles with more than 2 axles and a gross weight over 3.5 tonnes.

To assess how companies handled the compliance cost of these fees and adjusted their operations, interviews were conducted with representatives of major parcel delivery companies. We asked how significant the costs are, whether they can be passed along to customers explicitly, and what types of operational changes were made as a direct result of these policies. For instance, we asked whether their load factors had increased in response to the CCZ and LEZ. The number of interviews was limited by time and resource constraints, and the availability of an appropriate representative.

DATA ANALYSIS

Freight demand and pricing measures

Freight transport is used to meet the demand for goods. Freight is a derived demand – the demand is for goods supply, not freight transport in itself. Therefore goods demand and the extent of freight transport activity are not the same thing and do not necessarily have to move in the same direction or by the same magnitude Many goods vehicles are not full when operated there is excess capacity to carry more goods without necessarily adding vehicle journeys. The percentage of freight capacity that is used is called the load factor. While demand for goods normally increases with population growth, there could be more or fewer freight trips, depending on the size of vehicles and load factor. There was no publicly available data for the amount of freight moving around London, which would have allowed us to calculate load factor trends.

Freight operators normally pass along operating costs to customers, who in turn pass along the cost of goods supply to the public. In theory, compliance with the CCZ and LEZ could raise freight prices to the extent that it would affect demand for goods. Yet these fees are quite modest compared to the major freight cost drivers, labor and fuel. Given the relatively small proportion of vehicle operating costs and total distribution costs that the CCZ and LEZ accounts for, such a change in the demand for goods and services is unlikely.

Because freight is a derived demand, and customers set delivery times, they are expected to have limited sensitivity to pricing measures like congestion charging. TfL reported that inbound goods traffic decreased by about 10% when the congestion charge was first introduced, with commensurate increases on a diversion route, the Inner Ring road. [14] LGVs, especially vans driven by tradesmen, appeared to be much more sensitive to the charge than MGVs and HGVs, as they were more able to adjust the timing and routes of their trips.

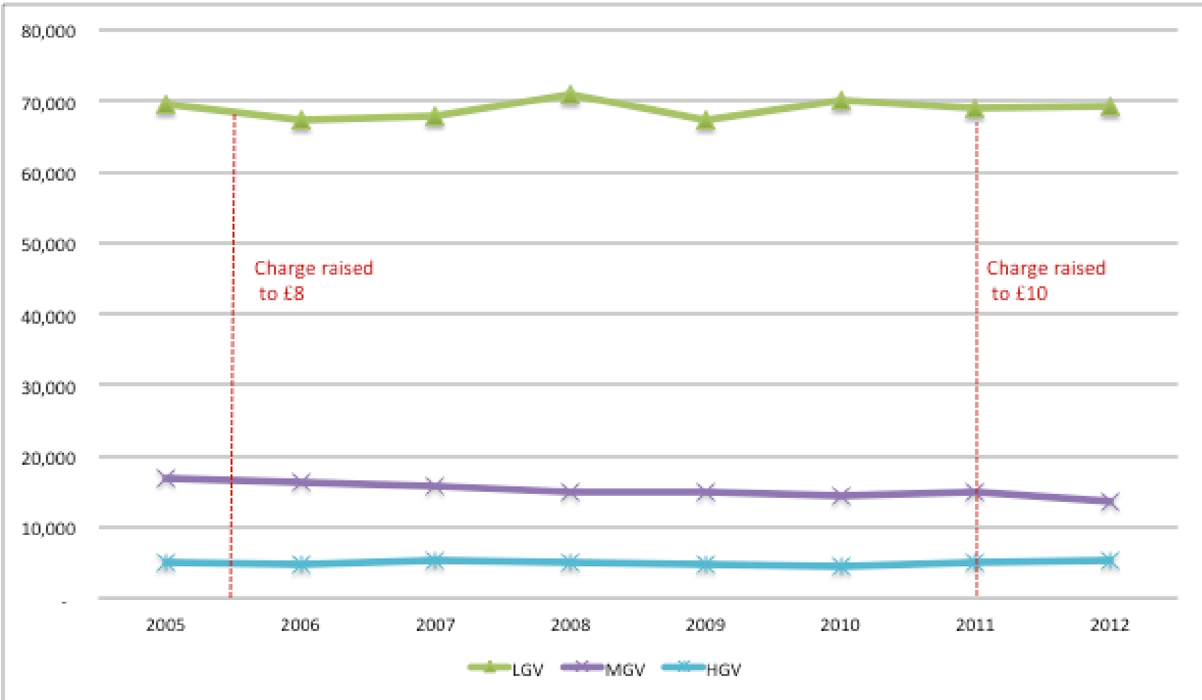
As would be expected based on this discussion, freight traffic has proven to be price inelastic. The congestion charge was raised to £8 in July 2005 (60% change in price), and then to £10 in January 2011 (25% change in price). Figure 3 shows counts of inbound goods vehicles at the central cordon, starting in Spring 2005. The volume of goods traffic remained stable after each of these price changes. We calculated the point elasticity of demand (percent change in quantity / percent change in price) using percent changes in traffic quantity from 2005 to 2006, and 2010 to 2011. TfL published elasticity estimates for car traffic of -.55 for the introduction of the £5 charge, and -.16 for the increase to £8, accounting for fuel and time costs. Our calculations for freight traffic are more simplistic, based on price change alone, and reveal a much lower sensitivity to price. Results are shown in Table 2.

For 2005 to 2006, when there was a 60% increase in price, a 3-10% decrease in goods vehicle traffic was observed, implying a low elasticity of -.06 to -.14. From 2010 to 2011, after a price increase of 25%, LGVs declined slightly, but MGV and HGV traffic increased, implying they are perfectly inelastic to price. As expected, LGVs were most likely to be able to adjust, and showed a consistent slight elasticity to these price changes. It could be that any trips which could be diverted by route or time were adjusted in the first few years, leaving a base level of the most essential trips in the long run. This base level of demand is driven by the economic cycle and is insensitive to pricing. Another possible explanation for stable traffic volumes in the face of rising prices is that operators have been consolidating loads, increasing load factors, improving efficiency over time, but we lacked the data to explore this.

TABLE 2. Elasticity estimates for goods vehicles

	2005 to 2006		2010 to 2011	
	Percent change	Elasticity	Percent change	Elasticity
LGV	-3%	-.06	-1%	-.04
MGV	-4%	-.06	3%	0
HGV	-9%	-.14	18%	0

FIGURE 3. Inbound goods vehicles entering CCZ during charging hours (7:00-18:00) [15]



Pricing measures like the London CCZ, by pricing discretionary traffic off the roads, are expected to benefit the freight sector in two main ways: travel time savings and journey reliability. In 2007, TfL estimated these benefits for Central, Inner and Outer London using a model based upon observed traffic volumes in each area. The model was based upon a £5 charge and the changes in travel speeds observed in the first year, not accounting for speed reductions from changes to the network, and so must be considered a maximum estimate. The CCZ was estimated to have reduced total VKT within the charged area by 17% (255,000 km per day), in Inner London by 2.5% (378,000 km per day) and Outer London by 1% (221,000 km per day). [15] Accounting for increased travel speeds due to these traffic reductions, and induced traffic in Inner and Outer London, the model estimated time savings per vehicle-kilometer to be 35 seconds for Central, 3.6 seconds for Inner, and 1 second for Outer London. This means a vehicle would save about one minute per mile driven in Central, per 10 miles in Inner, and per 62 miles in Outer London. The model estimated the value of improved journey reliability as 30% of travel time savings in the charging zone, but zero elsewhere (explained further in the report). The value of time savings for goods vehicle drivers were estimated as £.27 per minute.

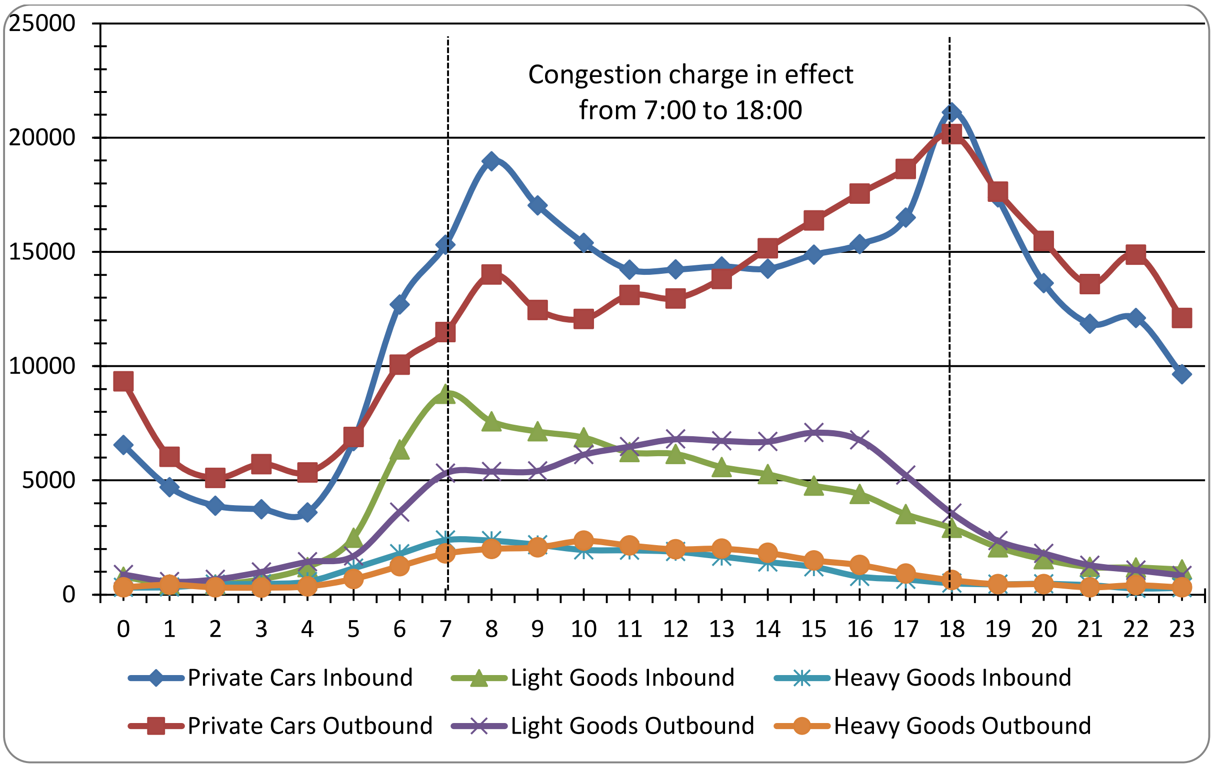
We used these values to estimate potential time savings for a freight operator. For instance, a delivery vehicle traveling 20 miles roundtrip from a depot in Inner London, and traveling an additional 20 miles making deliveries in the charged area would gain a time savings of 22 minutes per vehicle per day. The value of time and improved reliability would equate to about £8 per driver per day. These amounts would add up quickly for a fleet. Clearly, even though this is a best-case model, the time and reliability savings resulting from reduced traffic could add up to significant productivity gains for freight operators. Given such benefits, one might expect an increase in freight traffic.

Re-timing of trips

The CCZ was expected to shift some trips from the working day to the evening and night. This was clearly seen in aggregate traffic at the central cordon, where the proportion of daytime vehicle crossings dropped by 5% [16]. Disaggregation of the cordon data revealed that goods vehicles follow a different temporal pattern than private automobiles. Figure 3 shows vehicle counts by hour at the central cordon in 2012, as an example, as the patterns at the inner and outer cordons were similar. Private car traffic has two clear daily peaks in the morning and evening. Goods traffic only peaks in the morning, with outbound goods traffic trailing off gradually throughout the day. LGVs had the most similar pattern to private vehicles, showing a tendency toward an evening peak.

A consistent temporal pattern across all cordons suggests that freight operators lack discretion to shift trip times to avoid the congestion charge, as their schedule is driven by customer needs. Drivers of HGVs 3.5 tonnes and above are subject to drivers' hours restrictions meaning they must leave central London to take a break unless they have a place to park. LGVs may show a different pattern because they are less constrained in this regard. Inbound light goods traffic peaked at 7:00, when the congestion charge starts, meaning many were able to avoid the charge. Many of these vehicles, especially vans, are likely operated by small business tradespeople (e.g. electricians, plumbers, and builders) whose working hours match those of peak-hour commuters. Vans are often parked at residential addresses overnight and used for commuting to work and home.

FIGURE 3. Vehicles crossing the central cordon in London, by hour (2012) [17]



In interviews, freight operators reported they would prefer to avoid the congestion charge by having more flexibility to make out of business hours deliveries, as traffic flows are lower and there is greater availability of curb space, but they are constrained. Delivery hours and routes in London are restricted by the Boroughs, which set local on-street loading time restrictions and nighttime activity curfews on some supermarkets and offices. They also set the London Lorry Control Scheme, which restricts HGVs over 18 tonnes to certain main roads during nighttime and weekend hours. TfL has no jurisdiction over these restrictions, but has been assisting operators by setting up a Quiet Deliveries Consortium to enable dialogue. An agreement was reached for an out of hours deliveries trial during the 2012 London Olympics. During the trial, a greater proportion of goods vehicle journeys were made during the evening, night and early morning compared with summer 2011; HGVs did the most time-shifting [18]. Re-timing of goods vehicle operations was most significant in central London, indicating that heavy goods trips might shift to avoid the congestion charge if they were able.

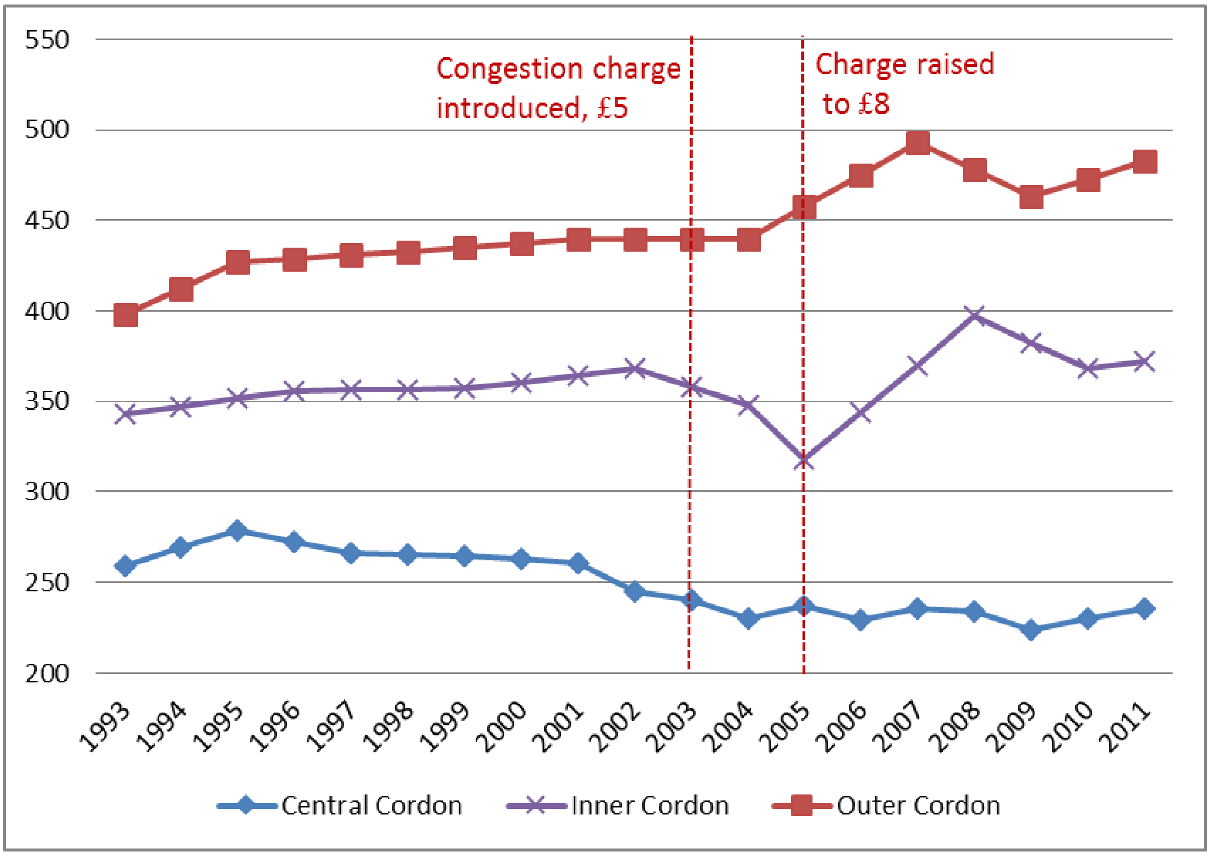
Based on the data available, it cannot be concluded that operators responded to the CCZ by re-timing trips. This aligns with other research showing that pricing has little influence on freight trip timing, because delivery/pickup times are set by the customer. A recent survey of freight operators found that 69% reported they cannot change their schedule due to customer requirements [19]. Among operators that have been able to shift deliveries to night hours, the CCZ is not likely the driver of change. Large retail operators with staff working during the night (eg Sainsbury, John Lewis) are most able to take advantage of these benefits of out of hours deliveries, and best able to avoid the congestion charge, because their sites receive full vehicle loads and are subject to dedicated logistics operations.

Re-routing of trips

The congestion charge was expected to shift some trips onto alternate routes, such as going around rather than through central London during charged hours. There is scant evidence that freight operators have been skirting the CCZ, increasing traffic volumes on orbital routes. The zone has a 'free' route running through it north-south (Park Lane) that enables operators and others to avoid the charged area while making a trip through central London. Orbital traffic flow counts showed a broadly similar pattern to cordon counts.

As shown in Figure 4, goods vehicles crossing the central cordon peaked in 1995, then declined until 2004, hovering around 240,000 vehicles per day on average after the CCZ took effect. By contrast, goods vehicles crossing the inner and outer cordons have been gradually increasing since the 1990s, with a higher rate of increase since the CCZ. The inner cordon showed a strange downturn around the 2005 data point and imputed values the two years before and after, perhaps due to road works in a critical area for these cordon counts. Notably, cordon counts at the inner and outer cordons continued upwards during the recession and then began to decline in 2008, when the LEZ went into effect.

FIGURE 4. Goods vehicles crossing London cordons, 24-hour counts (thousands) [16]



A differential impact at the central cordon is somewhat surprising, as the congestion charge was expected to deter discretionary trips but not freight. The CCZ may have accelerated an existing trend of declining goods traffic entering central London. It may have stabilized goods vehicle trips into central London, in spite of increasing population and employment density there. However, the available data is inadequate to clearly conclude that freight operators have changed the routing of trips to avoid the congestion charge. Another important factor in declining goods vehicle traffic in central London after 2001 is likely the relocation of logistics depots and warehouses from Central and Inner London to Outer London due to high land values – this is discussed in more detail later in the paper.

Reduced number of trips

London has experienced a long-term trend of declining traffic at the central and inner cordons, and stable traffic levels at the outer cordon since the late 1990s (as in Figure 4) [16]. Since car traffic declined while goods traffic increased (see Figure 1), goods vehicles are becoming a more prevalent proportion of traffic throughout London. From the late 1990s to early 2000s, goods vehicle traffic was stable and formed roughly 17% of traffic at all three cordons. [16] Starting in 2003, the proportion of goods traffic began increasing at all three cordons, such that in 2012, goods vehicles were roughly 20% of traffic at the central and inner cordons, and 19% at the outer cordon. The rising proportion of goods traffic likely reflects the disappearance of car traffic in Inner London after the CCZ came into effect.

The CCZ was expected to reduce the number of goods vehicle trips by encouraging operational efficiencies and consolidation, yet it was not focused on key factors driving demand for freight trips. Industry experts named population growth and rising demand for home delivery from online shopping as the most important drivers of freight demand [20-22]. Changes in the construction industry and tax incentives for small businesses have driven growth of light goods vehicle registrations, particularly vans [23]. It is possible, although publicly data available is not sufficiently detailed to provide the necessary evidence, that the absolute reductions in goods vehicle traffic in central London which commenced prior to the CCZ in 2001 (see Figure 4) resulted in part from greater vehicle load consolidation made possible by improved journey reliability and higher travel speeds provided by the CCZ. Interviewees commented that operating cost pressures from fuel, labor and parking violations were of greater importance to improving operational efficiency than the costs of the CCZ and LEZ. [24, 25]

London's efforts to reduce the number of goods vehicle trips extend beyond the CCZ policy, and some have been more successful. TfL supported development of freight consolidation centers, such as the Construction Consolidation Center demonstration program. During a pilot period from 2005 to 2008, the number of goods trips delivering to targeted construction sites in the City of London was reduced by 68%, and supplier journey times fell by two hours [26]. Experts said consolidation centers have been most successful in locations like Heathrow Airport where the landlord makes participation mandatory [22, 25]. Another trip-reduction measure piloted by TfL is consolidated delivery sites (click-n-collect) at rail stations. Operators saw this as an ideal solution for small and low value parcels, but expressed skepticism about consumers' willingness to utilize it [24, 25].

Another factor that could reduce the number of goods vehicle trips, as well as the length of trips and VKT, is warehouse storage space in central London. This is discussed in detail in the next section.

Reduced vehicle kilometers travelled

LGVs account for over three billion annual VKT in London, and HGVs for approximately one billion [2]. The CCZ was expected to reduce goods VKT by encouraging operational efficiencies such as freight consolidation, as discussed above, resulting in fewer trips and shorter trips. The LEZ was expected to have a mild VKT reduction effect by deterring non-compliant goods vehicles from passing through London, and by suppressing discretionary trips by other types of non-compliant vehicles. We mapped the spatial distribution of freight VKT by London borough to investigate whether these policies had discernible local effects. Figures 5 and 6 show average VKT per road mile over three time periods, from 1998 to 2002, from 2003 to 2007 (after the CC came into effect), and from 2008 to 2012 (after the LEZ came into effect).

In Figure 5, heavy goods VKT is highly concentrated in the eastern borough of Havering, where several intermodal freight facilities are located, as well as large industrial sites that are significant generators and attractors of freight trips. VKT levels were also high in the northern borough of Enfield where distribution centers are concentrated at Brimsdown, and along the western corridor between central London and Heathrow Airport in Hillingdon borough, (including a cluster of logistics centers at Park Royal in the boroughs of Brent and Ealing). VKT levels were also relatively high in the eastern industrial corridor along the Thames, in the boroughs of Tower Hamlets, Greenwich, Newham, and Barking and Dagenham. Over time, total heavy goods VKT declined from an annual average of 918 million kilometers per year in period 1 to 890 million in period 2 and 885 million in period 3, and retained basically the same spatial distribution.

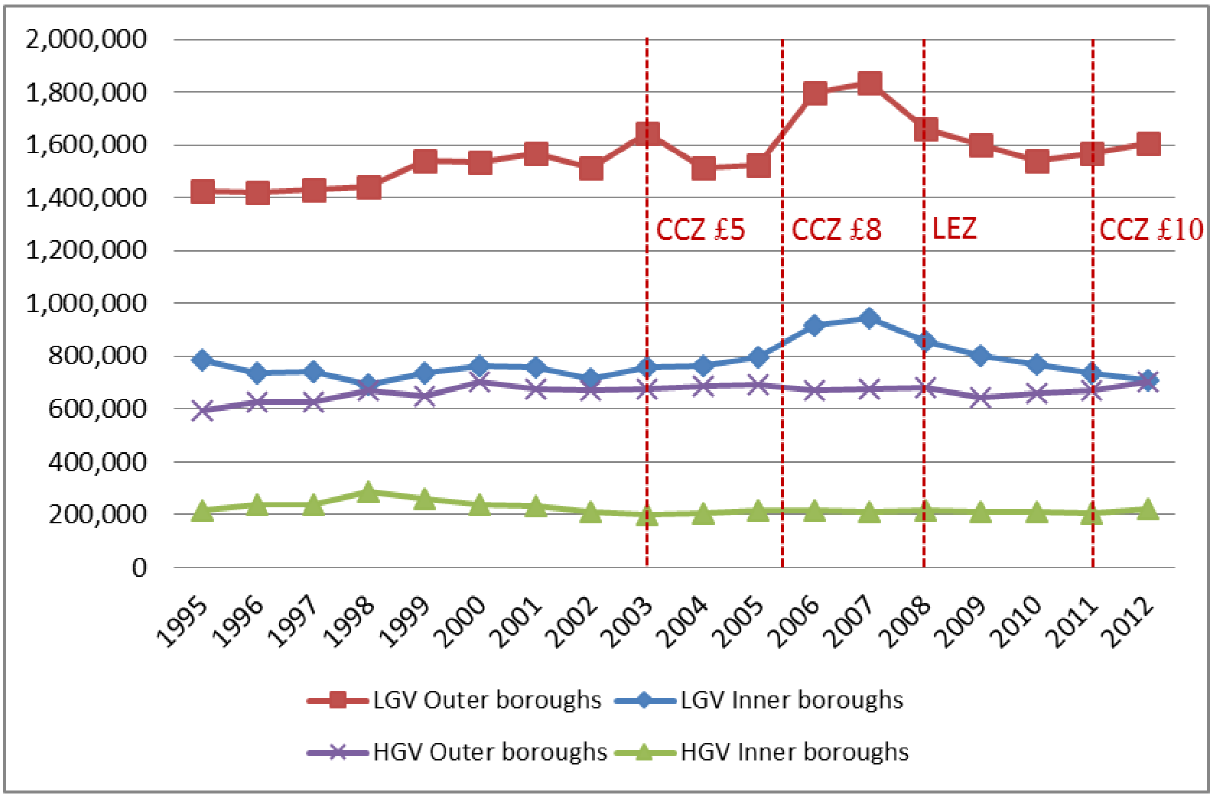
Figure 6 shows that light goods VKT is concentrated in the same edge boroughs of Havering, Enfield and Hillingdon, and along the eastern and western corridors, but it is more widely distributed throughout the region. Tower Hamlets borough, eastern adjacent to the City of London, shows high levels in part because it is where London’s secondary central business district, Canary Wharf, is located, and the surrounding area experienced significant growth over all three periods. Road infrastructure and river crossings are more limited in the east, and most traffic entering London must pass through Tower Hamlets, especially traffic from the south using Blackwall Tunnel. Over time, total light goods VKT increased from an annual average of 2.25 billion kilometers per year in period 1 to 2.45 billion in period 2, and then declined to 2.33 billion in period 3.

Evidence of VKT changes due to the CCZ, if any, would be seen starting in period 2 in the CCZ and Inner boroughs. For heavy goods traffic (Figure 5), period 2 shows a VKT decline in the City of London and several adjacent Inner boroughs, including Westminster, Kensington & Chelsea, Hammersmith & Fulham, and Hackney. Within the CCZ, in the City of London, heavy goods VKT averaged about 520,000 kilometers per year in period 1, but fell to 330,000 in period 2 and then grew to 360,000 in period 3. This pattern of steep decline, followed by a slow increase was similar in most Inner boroughs for heavy goods traffic. Yet it is clear the trend began in period 1, before the CCZ took effect.

For light goods traffic (Figure 6), period 2 shows an inverse pattern, one of increasing VKT in the City of London and most adjacent Inner boroughs, including those where heavy goods traffic declined. In the City, light goods VKT averaged about 1.25 million kilometers per year in period 1, grew to 1.42 million in period 2 and then fell back to 1.22 million in period 3. This pattern of moderate growth, followed by moderate decline was similar in most Inner boroughs for light goods traffic. It most likely followed the economic cycle, unrelated to the CCZ or LEZ.

The spatial patterns of both light and heavy goods traffic were remarkably stable over time, but a growing distinction can be seen between Inner and Outer boroughs. In both Figures 5 and 6, VKT declined most rapidly over time in the Central boroughs, especially those partially within the CCZ. This echoes the trend of declining goods traffic in Central London discussed earlier and illustrated in Figure 4. When freight VKT was disaggregated by Inner and Outer boroughs, as shown in Figure 7, it was evident that heavy goods traffic has been stable or declining in Inner London, and light goods traffic increased less than it has in Outer boroughs. It remains unclear whether these changing VKT patterns are directly related to the CCZ. They may be the result of several indirect and contradictory impacts, and complicated by industry trends unrelated to public policy or economic trends, such as substitution of smaller for larger trucks due to greater driver availability.

FIGURE 7. Annual freight VKT for Inner and Outer London (thousands) [2]

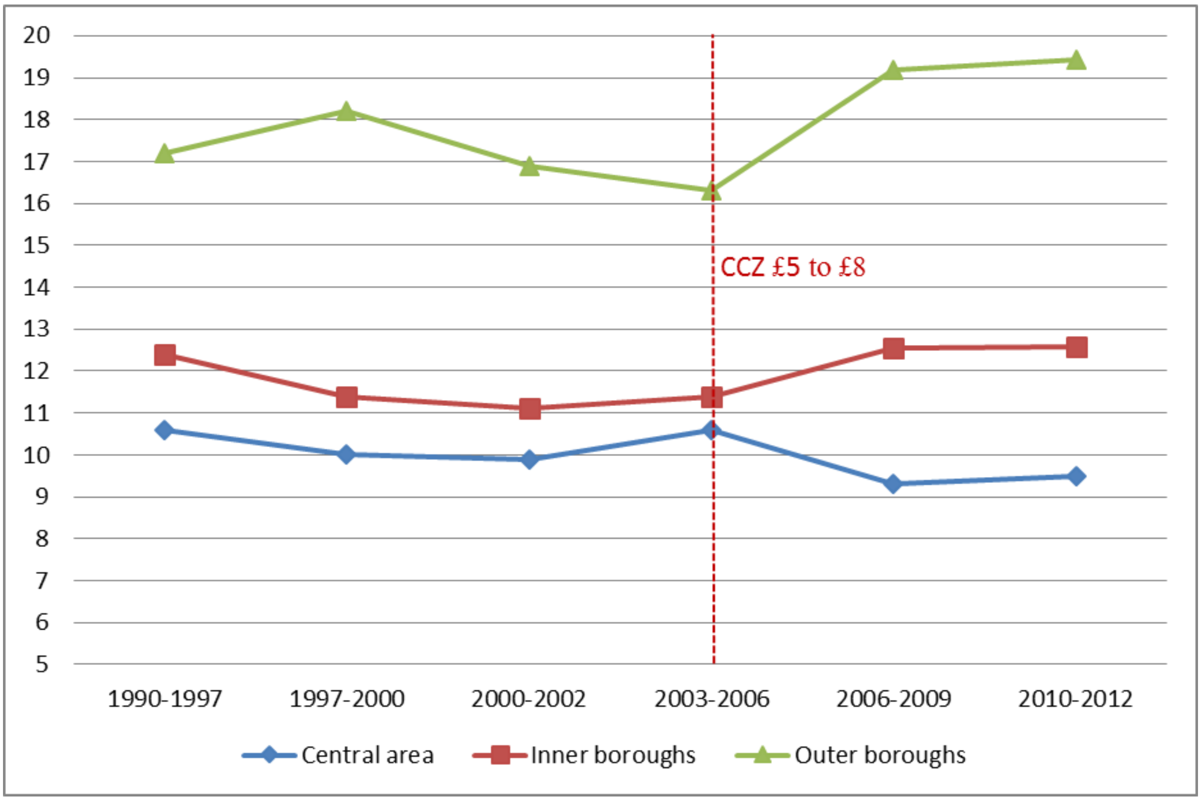


Travel speeds

Changes in travel speeds may be directly attributed to the CCZ, because this policy resulted in a significant reduction in traffic volume. We looked at average travel speeds for evidence of more attractive travel conditions. As shown in Figure 8, vehicle speeds increased in Inner London from about 11 mph in the early 2000s to 12.5 mph in the period 2006-2009 [8, 27]. Meanwhile, speeds within the central cordon fell from 10.6 mph in 2003-2006 to 9.3 mph in 2006-2009. Since light goods traffic increased in Inner London, and formed a greater proportion of traffic (as discussed above), it is likely the freight sector was able to reap the benefits of travel time savings and journey reliability throughout Inner London, a much larger area than the CCZ.

As discussed in the Introduction, travel speeds inside the CCZ have fallen back to pre-CCZ levels over the decade since it was implemented, mainly due to roadspace reallocation and signal timing changes prioritizing pedestrian safety. The freight sector was not differentially impacted by these changes to the street network, as care was taken to preserve curbside access for freight vehicles. Interviewees commented that they supported the new emphasis on pedestrian safety, as HGVs are responsible for a disproportionate share of pedestrian deaths, and they were taking further steps to upgrade safety and visibility equipment on their fleets. [22, 24, 25]

FIGURE 8. Average vehicle speeds on TfL strategic roads (miles per hour) [8, 27]



Land Uses

The location of warehouse space has a significant impact on the number and length of goods vehicle trips, and therefore VKT. The further out a depot is located from an urban center, the longer the minimum distance goods vehicles must travel to reach a delivery area (aka stem miles), increasing time and fuel costs. Operators reported that warehouse location had a direct impact on their costs, as typically diesel LGVs were deployed from suburban depots to higher density areas.

Industrial zoned land, warehouse properties and square footage of space have been in a long-term decline throughout London, most rapidly in Inner London where land costs have risen most rapidly. In 2000, London had 26 million square feet of industrial floorspace, with 61% located in Outer London, and 39% in Inner London. [28] This spatial distribution pattern has grown more pronounced over time. By 2012, only 32% was located in Inner London, where 5 million square feet of industrial floorspace was converted to housing and office uses. Almost all new industrial floorspace has been added in Outer London.

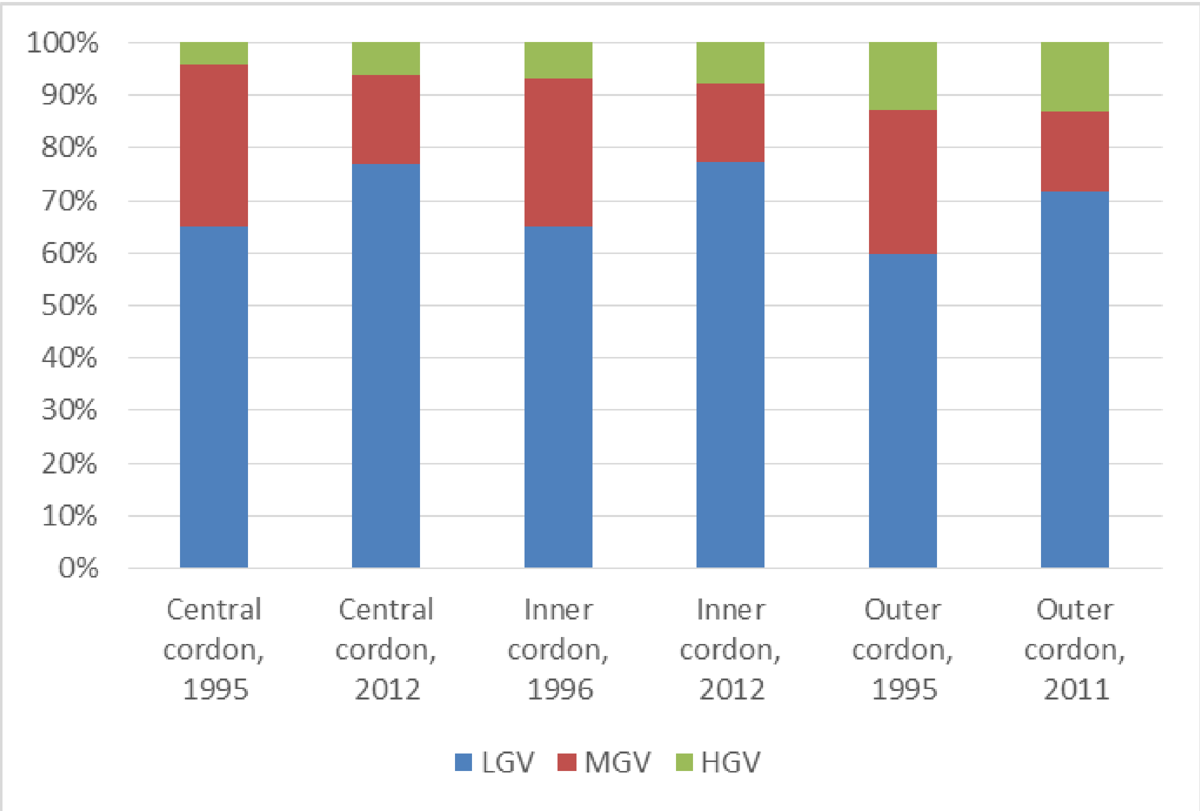
Replacing vehicles

The LEZ was expected to stimulate fleet turnover to less polluting vehicles. Goods vehicles operating in London may be registered inside or outside London. In 2012, there were 225,000 goods vehicles registered at London addresses, the vast majority LGVs [13]. A London registration does not mean that the vehicle is kept and used in London, likewise, vehicles kept and used in London may be registered elsewhere. TfL estimated that 725,000 to 860,000 vehicles were driven in the LEZ area in 2007, approximately 20% of which were over 12 tonnes [11]. A survey of operators undertaken during the LEZ public consultation found that most would purchase new vehicles to comply, while some with larger fleets would redeploy older vehicles outside the zone, and some would switch to smaller vehicles not subject to the regulation [29].

A study of vehicle registrations by Ellison et al. found evidence that the LEZ had a substantial effect on the composition of London's goods vehicle fleet. [28] They compared the replacement rate of goods vehicles in London to other areas of the UK from 2006 to 2011 and found it was higher in the years the LEZ Phase 1 and Phase 2 went into effect [30]. In 2007, London's proportion of 12 tonne goods vehicles older than Euro III was about the same as the rest of the UK in 2007 (47%), but had fallen to 32% by 2008. Similarly, the replacement rate of LGVs in London jumped by 10% over the rest of the UK in 2011, the year before Phase 2 LEZ regulations went into effect. The authors concluded the LEZ had spurred a one-time fleet turnover of 20% over the natural replacement rate among London-registered operators, but responses of those registered outside London were less clear. The total number of vehicles in London's freight fleet remained stable after the LEZ came into effect, but there was a shift among vehicle sizes. The proportion of LGVs increased by 3.3%, offset by a 3.3% decline in medium and heavy rigid and articulated vehicles. This apparent switching out of vehicle types was attributed to both the LEZ and increased demand for home deliveries from online shopping.

The cordon data corroborated a trend of substitution of light for MGVs. When goods vehicle cordon crossings were disaggregated by type of vehicle, we found the proportion of heavy vehicles has remained roughly stable since 1990, ranging from 5-6% of all traffic at the central cordon, 7-8% at the inner cordon and 13-14% at the outer cordon [16]. Meanwhile, the proportion of medium vehicles declined and light vehicles increased at all three cordons since the mid-1990s. For example, at the central cordon in 1995, medium vehicles were about 30% of goods traffic and light vehicles 65%, but by 2012 the proportions had changed to 17% and 77%, respectively [16]. Changes in vehicle proportions were similar at the inner and outer cordons, suggesting a long-term industry trend toward smaller vehicles from before the CCZ or LEZ came into effect. Driver regulations may be a contributing factor, as 7.5 tonne vehicles requiring a special license to drive can be replaced by large vans which do not, meaning more drivers are available [23].

FIGURE 9. Proportion of goods vehicle traffic at each cordon, by vehicle size [16]



DISCUSSION

Responding to concerns raised by freight operators

The public consultations on the CCZ and LEZ drew a lot of attention and many companies were actively involved when they were introduced. Despite TfL's assertions that the CCZ would lead to improvements in travel times in central London and hence the scope for operational efficiency gains, trade associations tended to disagree. For example, the

Confederation of British Industry (CBI) and the Freight Transport Association (FTA) both argued that any travel time savings would be too small to facilitate additional delivery work on a vehicle journey. [23] During the initial CCZ consultation, freight operators argued for an exemption on the basis that their trips were not discretionary and could not be shifted to a different mode, route, or time of day. They argued their trips are driven by customer demand, making the congestion charge essentially a tax on their business. Operators see themselves as promoting the economy, like taxis, which were exempted; some argued they provide an essential service, like ambulances, which were also exempted. TfL considered taxis part of the public transportation system and essential services as public sector. Some operators continued to seek an exemption during the most recent CCZ public consultation in Spring 2014, while others declined to participate, seeing it as entrenched.

TfL has never altered its position on a freight exemption, but its responses to other concerns have been well received. When the CCZ was first introduced, operators had to make individual payments. Since 2008, a new automated system allows freight operators to register vehicles and make bulk payments, which has greatly reduced the administrative burden. Initially, only operators with 25 or more vehicles qualified for the £1 per vehicle fleet discount, but it was reduced to 9 vehicles in 2008 and 6 vehicles in 2014.

In lieu of exemptions to the LEZ, TfL developed a voluntary membership scheme that is available free of charge to any company operating vans or lorries in London. The Freight Operator Recognition Scheme (FORS) was launched in 2008 and provides operators with practical advice and guidance to help reduce fuel consumption, CO_2 emissions, vehicle collisions, and penalty charges. This is achieved through improving driver behavior, vehicle and fleet management, and efficiency and safety in transport operations. The program is delivered through company training, workshops and electronic guides and tools. Three levels of FORS certification are available: bronze, silver and gold. These are attained through the degree of implementation of systems, policies and procedures, together with the provision of operational data for benchmarking purposes, the production and achievement of an excellence plan, and on-going independent assessment and monitoring. TfL provides assistance to help operators comply with the LEZ, CCZ and other rapidly changing safety, parking and loading regulations. The requirement of FORS certification is being increasingly adopted as a requirement in private and public sector procurement contracts. By 2013 approximately 145,000 goods vehicles operating in London were registered in FORS [13].

Achieving operating efficiencies

As shown in Figure 6, London's central charged area is being served by a stable or declining number of goods vehicles even as the number of residents and firms has grown there. The CCZ suppressed private automobile traffic, reduced travel delay and improved journey reliability within the CCZ and throughout Inner London [15]. These trends imply that several efficiencies might be in play. Freight operators may have become more operationally efficient, serving a similar or growing customer base with less travel time delay or with fewer vehicles.

We asked operators whether the congestion charge had encouraged operational efficiencies. They said it was one of several costs driving efficiency, but not nearly as significant as rising fuel and labor costs, and a shrinking customer base during the recession; it was characterized as a cost they had learned to live with [24, 25]. The level of the charge was considered too low, and the market too competitive, to respond by adding a surcharge on central London deliveries. Industry experts speculated most operators absorbed the charge or manages to pass it along to customers, either through higher prices or higher contract charges [22, 23]. There was concern that smaller operators might be unable to do either, and so withdraw from the central London market, making it a niche market with higher delivery costs [22].

Parking violations were a greater cost concern than the CCZ or LEZ. A typical delivery vehicle risks a £65 ticket during each of its dozens of stops per day, which, given the complexity of curbspace regulations managed by different units of government and enforced with varying intensity, can add up to six figures for large operators. For comparison, one operator estimated the annual CCZ compliance cost was approximately £2,200 per vehicle operating in central London; it would take only twelve days to exceed that amount with LEZ violations. [25]

When we asked whether operators had benefited from travel time savings, they responded that time savings were noticeable in the early years of the CCZ, but have eroded away as congestion levels have crept upwards [22, 24, 25]. When it was first introduced, traffic volumes in the zone fell by 20% and have remained stable, however, physical and operational changes to the street network have reduced network capacity and average travel speeds since its introduction [8]. Some operators commented they were not getting value from the charge, and one noted that while the CCZ had helped realize time savings over the past ten years, more valuable operating efficiencies such as increased load factors and drops per route were achieved due to internal factors [24]. These perceptions of CCZ benefits may not take account of time savings and journey reliability improvements throughout Inner London. Perceptions may also reflect the difficulty of comparing against how much worse congestion might have been without the CCZ.

In theory, freight operators should be able to achieve operational efficiencies from increasing spatial density of residential and commercial delivery addresses. When asked whether increasing customer density in the charged area helped reduce their costs, operators said no, because of how they calculate their costs. Costs are calculated based upon the number of stops a vehicle can make in a typical workday, rather than on a per delivery basis. This measure does not reflect an efficiency gain such as increased parcels per stop. It is more sensitive to constraints on the delivery window, such as nighttime curfews, because drivers are forced into peak traffic and can make fewer stops per day per vehicle. Operators said CCZ would be more palatable if it were accompanied by reforms to expand the delivery window.

An indirect effect of the LEZ and CCZ, which together send a strong signal to freight operators about London's commitment to sustainability, was to spur some operators to experiment with electric vehicles (EVs). Both parcel operators we interviewed reported EV pilot programs at their central London depots using custom-built or custom modified vehicles, because appropriate freight EVs are not yet commercially available [24, 25]. EVs were expected to help reduce fuel and excise duty costs, as well as gain exemption from the LEZ and CCZ.

Improving spatial efficiencies

As neither the CCZ or LEZ directly impacted factors driving freight VKT, in this section we discuss a missed policy opportunity. VKT could be more effectively reduced by encouraging spatial efficiencies that reduce and shorten trips through the location of logistics centers. Operators reported they would prefer to bring freight into central London in bulk with large vehicles at night, and then deploy small vehicles for short trips, preferably EVs [24, 25]. Such bundling and centralization would reduce the number of LGVs on roads throughout London during peak hours, and also VKT and emissions from those vehicles.

The constraint that operators face in this context is availability of suitable warehouse space in central locations where land values are very high. Freight depot locations are determined mainly by land market values and local planning permission. In most urban areas, as land values rise in the center, industrial uses are pushed further and further out. [31] Over the period 1998-2008, warehouse floorspace was rapidly disappearing in most Inner London boroughs, especially those partly within the CCZ (e.g. 82% in the City of London, 51% in Westminster) [32]. Meanwhile, warehouse growth was strong in many Outer London boroughs (e.g. 34% in Enfield, 21% in Havering).

Policies protecting some central urban locations for logistics might be more effective than pricing in reducing VKT. For instance, if a company with a fleet of 100 vehicles was forced to relocate its operations from a central location to a suburban depot 10 kilometers away, that could add up to 500,000 extra annual VKT, (assuming 20 round-trip kilometers x 100 vehicles x 250 working days). Allowing freight depots to be continuously pushed to the periphery of the urban area works against sustainability and VKT reduction policies.

Another possibility to reduce VKT is improving the spatial efficiency of delivery sites. TfL recently introduced a "click-n-collect" service at some Underground stations, where customers can collect goods from secure lockers. By consolidating deliveries in one place, these services reduce VKT and improve efficiency for freight operators. Operators were skeptical of customer demand for this service, but it has proven popular, with more than 10,000 orders delivered in the first ten months. [33]

CONCLUSION

The LEZ appeared to spur higher levels of operational change than the CCZ. This might be expected, as the fee level was sufficiently high to create economic pressure, it was applied to all operators at all times throughout London, and compliance could be achieved by a one-time action. It was made palatable as a measure linked strictly to air quality that applied to all vehicles equally, even personal and civic vehicles. The CCZ was low enough to be absorbed or passed along by freight operators, even as it was raised over time. Measures that help to reduce the compliance burden, such as an automated payment system, should be introduced right away. Rather than a fleet discount, which gives an additional advantage to large operators, discounts should be directly aligned with the goals of the CCZ.

The CCZ may have time-shifted some trips by LGVs owned by small businesses, but it was insufficient on its own, to shift the timing of freight trips with delivery window constraints. The CCZ would be more palatable to freight operators if accompanied by flexibility for out of hours deliveries, which may require the cooperation of local governments. There was insufficient data to determine whether operators were re-routing trips to avoid the CCZ, but there was a trend of declining freight VKT in the central boroughs partly within the zone. There was no evidence of avoidance traffic on orbital routes, in part due to a ‘free route’ for through traffic. Heavy goods vehicle traffic tended to grow at a slow steady rate over time and was inelastic to pricing but sensitive to delivery time constraints, meaning there is greater potential to time-shift this traffic through changes to nighttime delivery curfews. Light goods traffic was more sensitive to the economic cycle and to public policies like pricing, driver regulations and tax incentives for small businesses. This sector appears to be growing for many reasons, and meaning there may more potential to reduce emissions through vehicle standards than VKT reduction measures. Neither the CCZ nor LEZ had any effect on a key driver of VKT, the dispersion of logistics centers to suburban sites that increase driving distances between the freight depot and the first delivery site. A policy protecting freight sites in central areas could be more effective.

Increasing freight VKT in Inner boroughs suggests that operators’ perceptions of CCZ benefits may not take account of time savings and journey reliability improvements throughout Inner London. Perceptions are affected by the difficulty of comparing against how much worse congestion might have been without the CCZ. Operators can be highly cooperative engaging with policymakers on initiatives that help solve persistent issues that affect their business, like delivery window constraints and keeping up with rapidly changing loading and parking restrictions. Such initiatives can help offset discontent over lack of exemptions and discounts from policies like the CCZ and LEZ.

References

1. TfL, *Travel in London Report 5*. 2012, Transport for London: London.
2. DfT, D.f.T., *Road Traffic Estimates*. 2013, UK Department for Transport: London.
3. TfL, *LEZ Guide for Operators*, T.f.L.F. Unit, Editor. 2012, Transport for London: London.
4. Census, *UK Census*. 2011, UK Data Service Census Support: London.
5. ABI, *Annual Business Inquiry*. 2013, Office for National Statistics: London.
6. ONS, *International Passenger Survey*. 2014, Office for National Statistics: London.
7. VOA, *Property Rating List*. 2010, Valuation Office Agency: London.
8. TfL, *Travel in London Report 6*. 2013, Transport for London: London.
9. Barry, J., *Head of Bus Network Development, Transport for London*. 2014, Personal interview. April 7, 2014.
10. GLA, *Greater London Low Emission Zone Charging Order*. 2006, Greater London Authority: London.
11. TfL, *London Low Emission Zone: Impacts Monitoring Baseline Report*. 2008, Transport for London: London.
12. TfL, *TfL's Report to the Mayor on the Low Emission Zone Variation Order Consultation*. 2010, Transport for London: London.
13. Allen, J., M. Browne, and A. Woodburn, *London Freight Data Report: 2013 Update*. 2013, Transport for London Freight Unit: London.
14. TfL, *Congestion Charge Impacts Monitoring, Second Annual Report*. 2004, Transport for London: London.
15. TfL, *Central London Congestion Charging Scheme: ex-post evaluation of the quantified impacts of the original scheme*. 2007.
16. TfL, *TAC Traffic Note 3: TfL Cordon and Screenline Surveys, 1971-2011*, C. Brady, Editor. 2013, Transport for London Network Performance, Traffic Analysis Centre: London.
17. TfL, *TfL Cordon Counts*. 2012, Transport for London, Freight Unit: London.
18. Allen, J., M. Browne, and A. Woodburn, *London Freight Data Report: 2012 Update*. 2012, Transport for London Freight Unit: London.
19. Holguín-Veras, J., *The truth, the myths and the possible in freight road pricing in congested urban areas.* Procedia - Social and Behavioral Sciences, 2010. **2**(3): p. 6366-6377.

20. Bolitho, A., *Property, Energy and Transport Policy Adviser, Retail Consortium*. 2013, Personal interview. November 21, 2013.

21. Barrett, P., *Public Affairs Manager, London Chamber of Commerce*. 2013, Personal interview. November 29, 2013.

22. Chapman, N., *Head of Policy for London, Freight Transport Association*. 2013, Personal interview. October 27, 2013.

23. Browne, M., *Professor, Westminster University*. 2014, Personal interview. April 20, 2014.

24. Currie, R., *Director of Public Affairs, UPS Europe*. 2014, Personal interview. April 25, 2014.

25. Schulz, M., *City Logistics and Public Affairs Manager, TNT Express*. 2014, Personal interview. April 9, 2014.

26. TfL, *London Construction Consolidation Centre Final Report*. 2009, Transport for London Freight Unit: London.

27. TfL, *Travel in London*. 2007, Transport for London: London.

28. VOA, *Business Floorspace Statistics*. 2012, Valuation Office Agency London.

29. Browne, M., J. Allen, and S. Anderson, *Low Emission Zones: The Likely Effects on the Freight Transport Sector*, in *Logistics Research Network Conference*. 2004: Dublin.

30. Ellison, R., S. Greaves, and D. Hensher, *Five years of London's low emission zone: Effects on vehicle fleet composition and air quality.* Transportation Research Part D: Transport and Environment, 2013. **23**(0): p. 25-33.

31. Dablanc, L. and D. Rakotonarivo, *The impacts of logistics sprawl: How does the location of parcel transport terminals affect the energy efficiency of goods' movements in Paris and what can we do about it?* Procedia - Social and Behavioral Sciences, 2010. **2**(3): p. 6087-6096.

32. Allen, J., M. Browne, and T. Cherrett, *Investigating relationships between road freight transport, facility location,logistics management and urban form.* Journal of Transport Geography, 2012. **24**: p. 45-57.

33. TfL. *Major retailers to bring 'click and collect' revolution to the London Underground network.* Transport for London, Press release, January 29, 2014.

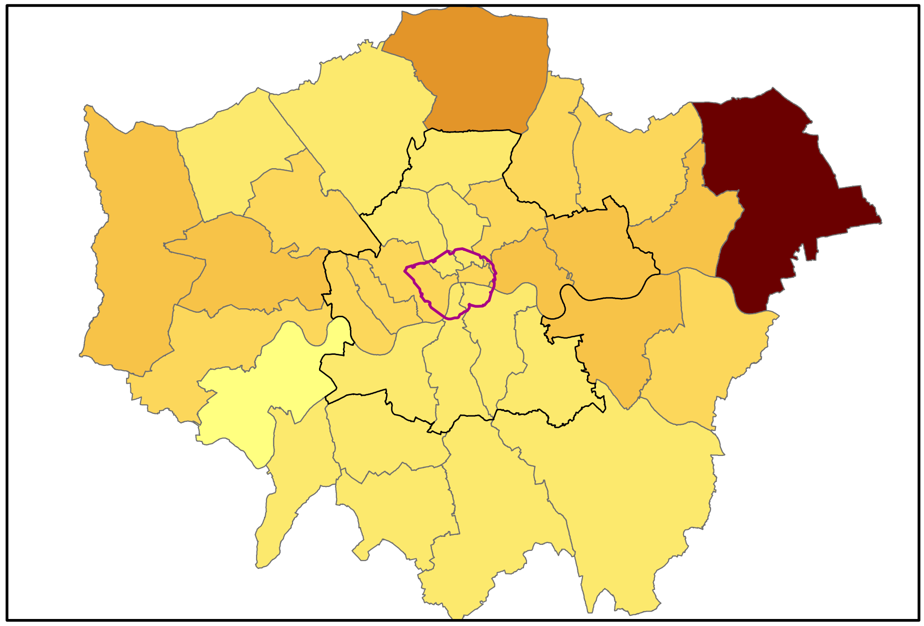
FIGURE 5.

Heavy Goods Vehicles Average Annual VKT per road km (major roads only)

CCZ
Inner boroughs
VKT per road km
1 - 200
201 - 400
401 - 600
601 - 800
801 - 1,000
1,001 - 1,200
1,201 - 1,400
1,401 - 1,600
1,601 - 1,800
1,801 - 2,000

Period 1
1998 to 2002

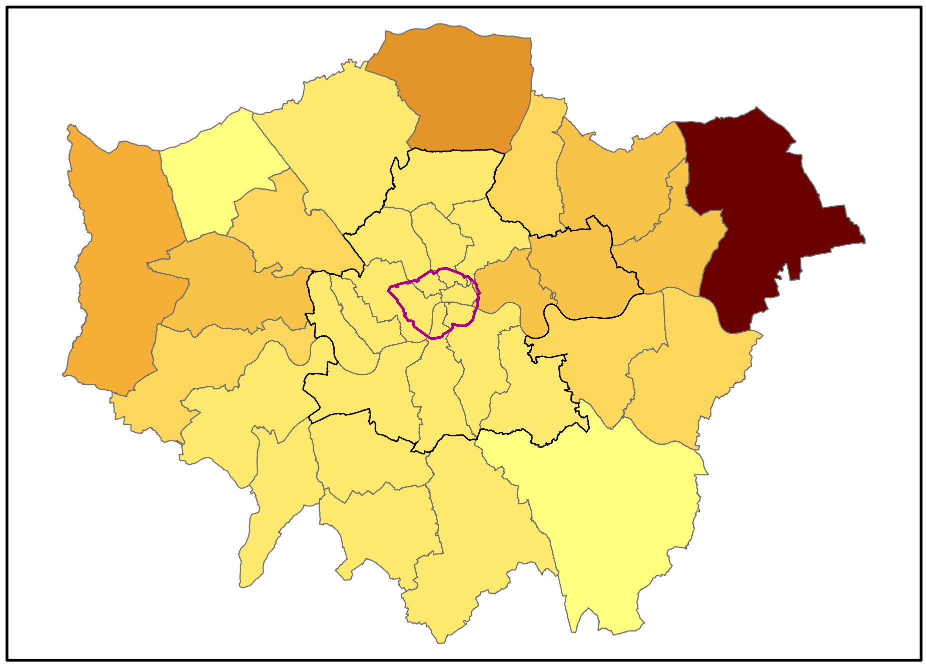
Greater London total
Average annual VKT
918 million



CCZ
Inner boroughs
VKT per road km
1 - 200
201 - 400
401 - 600
601 - 800
801 - 1,000
1,001 - 1,200
1,201 - 1,400
1,401 - 1,600
1,601 - 1,800
1,801 - 2,000

Period 2
2003 to 2007

Greater London total
Average annual VKT
890 million



CCZ
Inner boroughs
VKT per road km
1 - 200
201 - 400
401 - 600
601 - 800
801 - 1,000
1,001 - 1,200
1,201 - 1,400
1,401 - 1,600
1,601 - 1,800
1,801 - 2,000

Period 3
2008 to 2012

Greater London total
Average annual VKT
885 million

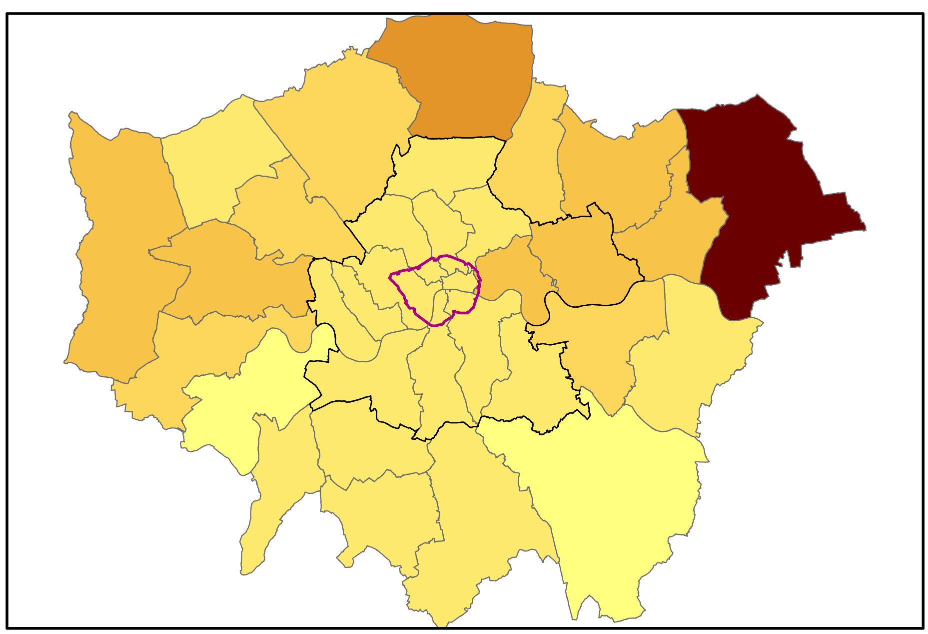


FIGURE 6.

Light Goods Vehicles Average Annual VKT per road km (major roads only)

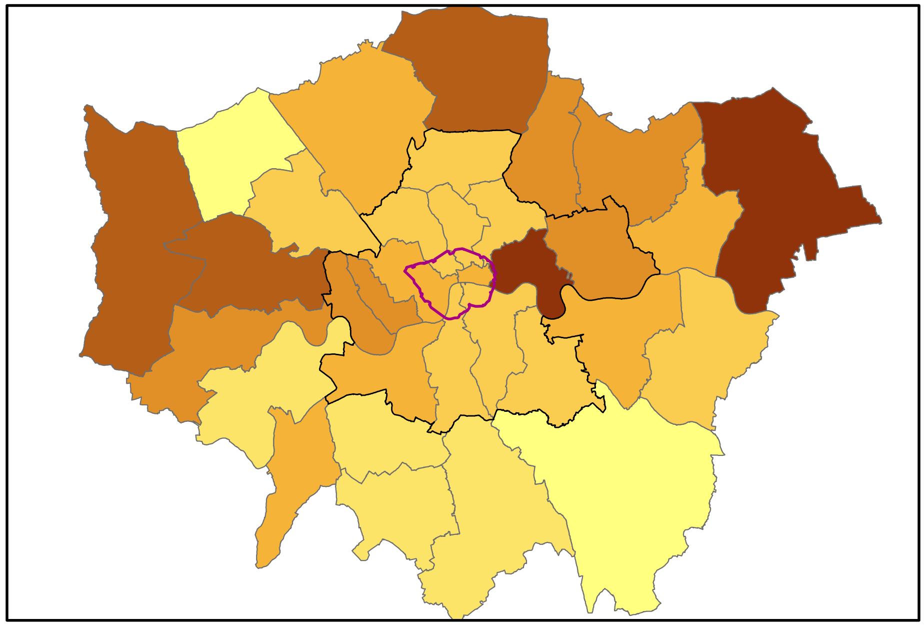
CCZ
Inner boroughs

VKT per road km

601 - 800
801 - 1,000
1,001 - 1,200
1,201 - 1,400
1,401 - 1,600
1,601 - 1,800
1,801 - 2,000
2,001 - 2,200

Period 1
1998 to 2002

Greater London total
Average annual VKT
2.25 billion



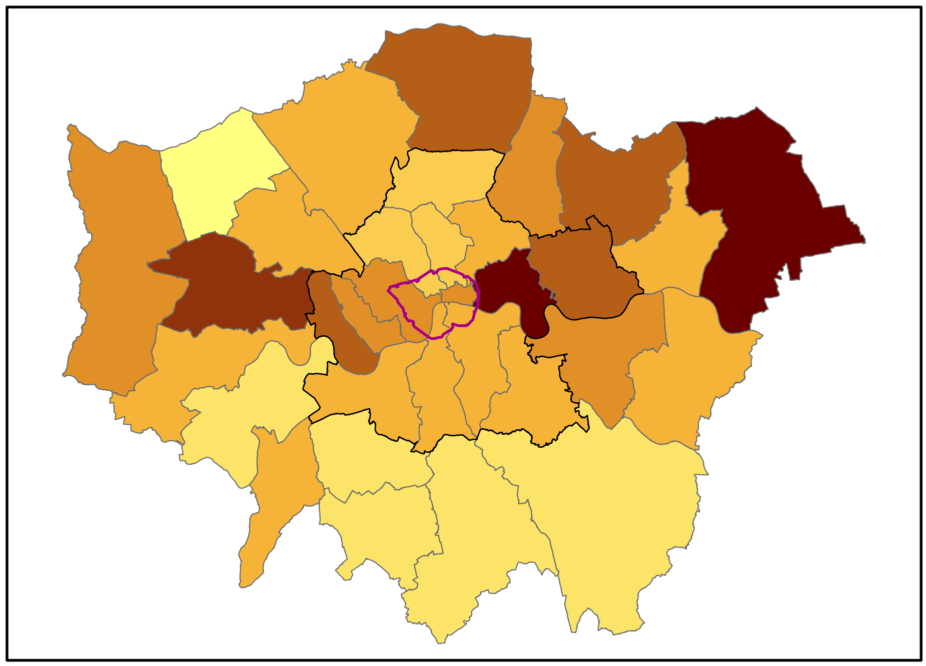
CCZ
Inner boroughs

VKT per road km

601 - 800
801 - 1,000
1,001 - 1,200
1,201 - 1,400
1,401 - 1,600
1,601 - 1,800
1,801 - 2,000
2,001 - 2,200

Period 2
2003 to 2007

Greater London total
Average annual VKT
2.45 billion



CCZ
Inner boroughs

VKT per road km

601 - 800
801 - 1,000
1,001 - 1,200
1,201 - 1,400
1,401 - 1,600
1,601 - 1,800
1,801 - 2,000
2,001 - 2,200

Period 3
2008 to 2012

Greater London total
Average annual VKT
2.33 billion